



The Solutions Network  
Rochester, New York

# Cool, Comfortable, and Productive

Michael West, PhD, PE  
Building Systems Scientist  
Advantek Consulting, Inc.



Maintenance  
1%

Energy  
1%

Facility  
14%

Salaries  
84%

**Annual Square Foot Costs  
Typical Office Building**

*1% productivity gain = energy costs*

*1 hour salary = annual office lighting cost*

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## What is IEQ?

- ❖ Under **ordinary** conditions:
  - Lighting
  - Noise
  - Ergonomics
  - Comfort
  - Indoor Air Quality (IAQ)
- ❖ Under **extraordinary** conditions:
  - Terrorism
  - Airborne CBR attack

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## What is Productivity?

- ❖ In the **private sector**:
  - Cost of resources versus profit
- ❖ In **government**:
  - Resource requirements
  - Accountability and progress towards goals
  - Outputs must be countable, similar over time, significant (their absence would be a cause for change), and the end result of some process.
  - Overall agency versus single work unit
  - Difficulty of measuring something that is not clearly defined

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



*"The most important contribution of management in the 20<sup>th</sup> century was to increase manual-worker productivity fifty-fold.*

*The most important contribution of management in the 21<sup>st</sup> century will be to increase knowledge-worker productivity--hopefully by the same percentage. So far it is abysmally low and in many areas (hospital nurses, for instance, or design engineers in the automobile industry) actually lower than it was 70 years ago."*

Peter Drucker

Knowledge-Worker Productivity: The Biggest Challenge, 1999.

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



*If we show IEQ **can**  
improve productivity...*

*... then we have very strong justification of  
\$'s for design, equipment and operations  
improvements*

*that create performance benefits and pay  
for themselves over time*

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE





## ❖ IEQ affects our higher mental activities

### ➤ It must be...

- Safe and Secure
- Comfortable
- Feel Good (smell, sight, sound, touch)

### ➤ ... for us to perform at our best

- Concentration / Task Immersion
- Focus / Task Speed
- Mental Agility
- Verbal Skills
- Creativity
- Health and well-being

August 8-11, 2004

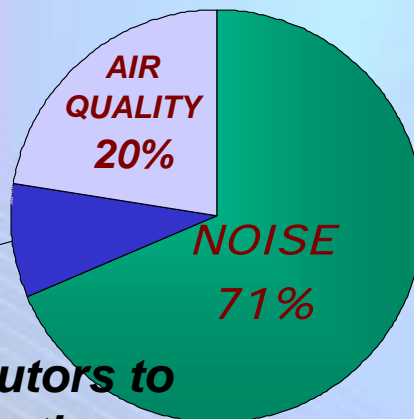
www.energy2004.ee.doe.gov

Michael K. West, PhD, PE



According to the Building Owners and Managers Association (BOMA), **thermal discomfort is the number one reason tenants do not renew a lease.**

**LIGHTING**  
**9%**



## **Reported Contributors to Workspace Distraction**

American Society of Interior Design, "Increasing Office Productivity Through Integrated Acoustic Planning And Noise Reduction Strategies"

August 8-11, 2004

www.energy2004.ee.doe.gov

Michael K. West, PhD, PE



## One experiment showed this:

### TASKS:

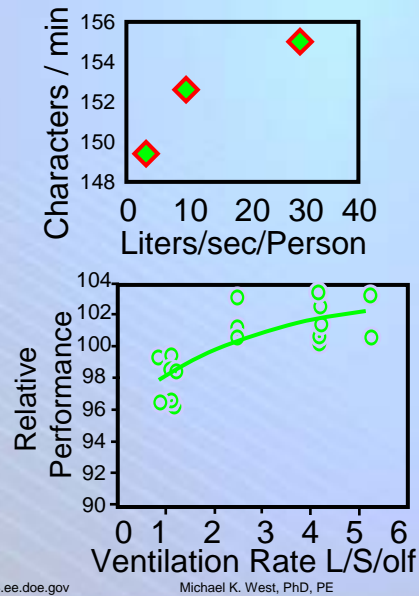
- Verbally respond to questions
- Typing at computer
- Addition
- Proof reading

### IEQ Problem:

20-year old carpet  
from "sick" building

### RESULT:

Productivity increased  
with increasing ventilation



Wargocki, P., Balik, Y.K., Fanger, P.O. Impact of pollution emitted from a carpet on SBS-symptoms and productivity in offices" Proc. of DKV-Tagung '98, Wurzburg, 18-20 Nov. 1998

August 8-11, 2004

www.energy2004.ee.doe.gov

Michael K. West, PhD, PE



## Ventilation & Sick Leave

**Polaroid Corporation / Boston:**

**50% sick leave decrease**

ventilation 25 cfm versus 50 cfm

Cost \$80, savings \$400, per worker per year

**U.S. Army Barracks:**

**45 -56 % fewer respiratory disease cases**

in old drafty barracks compared with AC barracks:

Crowding? Bathroom Design? Humidity?

**Gulf War Barracks, Saudi Arabia**

**+39% sore throat, +19% cough**

AC housing compared with Non-AC housing

Milton, et al., "Risk of sick leave associated with outdoor air supply rate, humidification, and occupant complaints" *Indoor Air* 10 (4): 212, 2000  
Brundage JF, Scott RM, Lednar WM, Smith DW, Miller RN. 1988. Building-associated risk of febrile acute respiratory diseases in army trainees. *JAMA* 259(14):2108.  
Richards AL, Hyams KC, Watts DM, Rozmajzl PJ, Woody JN, Merrell BR. 1993. Respiratory disease among military personnel in Saudi Arabia during Operation Desert Shield. *American J. Public Health* 83(9): 1326-1329.

August 8-11, 2004

www.energy2004.ee.doe.gov

Michael K. West, PhD, PE





## Landmark Studies

- West Bend Mutual Insurance Company
  - New building with Personal Environment Modules (PEM)
  - 16% productivity increase of which 2.8% was PEM
    - Rensselaer Polytechnic Institute
- Medical Call Center
  - Increase of fresh air ventilation to within 75-ppm<sub>CO2</sub> outdoor
  - 2% productivity increase
    - Lawrence Berkeley National Laboratory
- Office Building
  - Individual temperature controls within a range of 5-degrees F
  - 7% faster typing and 3% overall productivity increase
    - Wyon D.P.

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## Are these studies conclusive?

*"Research on this topic is difficult because of the complexity of defining and measuring performance in real-world environments and because many factors, including worker motivation, influence performance."*

– William J. Fisk, Lawrence Berkeley National Laboratory

- ❖ Review of Numerous Studies
- ❖ Overall results show productivity increases of 2 to 20%
- ❖ Range of performance improvement **½% to 5%**
  - Fisk W.J. 2000. "Estimates of potential nationwide productivity and health benefits from better indoor environments: an update"

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## IEQ Affects Employee Satisfaction



August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## Measuring Productivity

- Workers must participate
- Simplify unmeasurable complex processes into measurable sub-processes
- Use the best measure for each job
- Do not expect absolute accuracy
- "Productivity" versus "Performance"
- Researcher and time independent
- Measuring is better than not measuring

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## Productivity Evaluation Components

Component	Description
Decision Making	Application of knowledge, unlike simple choices such as "stamp" or "do not stamp."
Complexity	Number and difficulty of decisions and the amount of knowledge needed.
Knowledge Use	The amount and complexity of information required to do the work.
Structured	Constraints on how, when, where, and what is done.
Repetitive	A function done the same way every time, and will always be done the same way.
Volume	The number of times the profiled activity will occur in a given time cycle.
Time per Job	The total time spent completing the job, from start to finish.
Skilled Activity	The physical difficulty of performing the work.

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



❖ Let's just go with 1%.

August 8-11, 2004

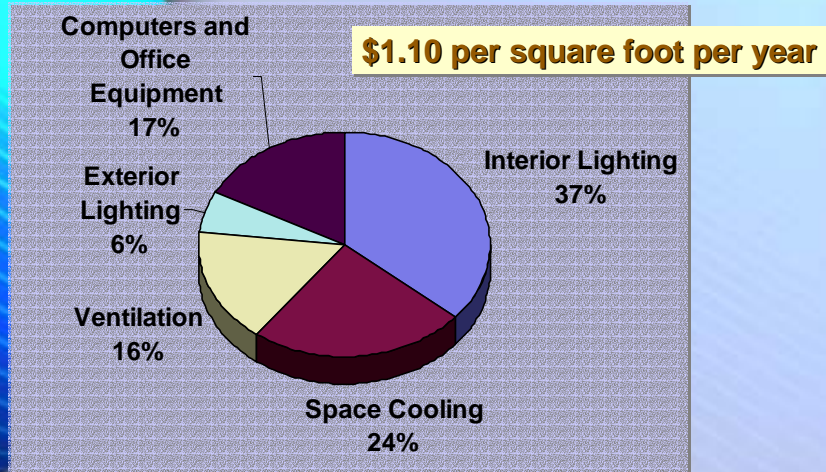
[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE





## TYPICAL ENERGY COSTS Office Building



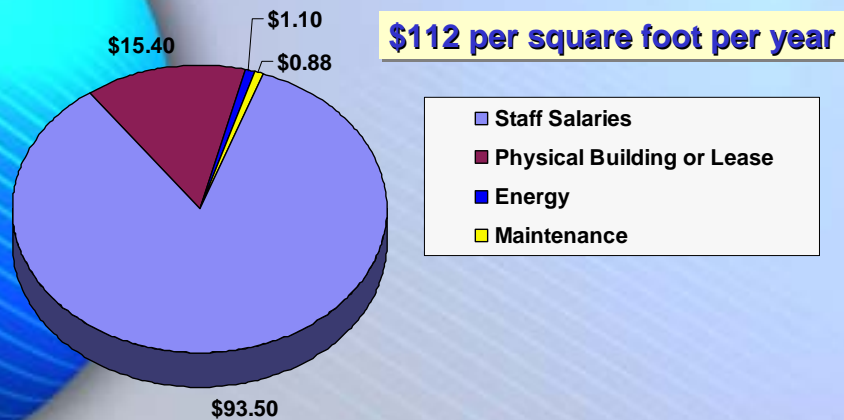
August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## ALL COSTS Typical Office Building



August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## TYPICAL STAFF COSTS Office Building

**\$93.50 per square foot per year**

Reality Check: 300 square feet per person  
 $\$93.50 \times 300 = \$28,050$  per person per year

**A staff of 100 people, with a 1% productivity increase,  
can do the work of 101 people?**

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



### ❖ It depends on that 101<sup>st</sup> person.

- skill set / type of work
- best to worst range is 3:1 (300%)\*
- staff distribution
- management & training
- *numerous* other factors

### ❖ Let's just say they *can* do it.

\*Thuesen, G.J. Engineering Economy

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## Value of a 1 % Productivity Gain

**\$0.94 per square foot per year**

30,000 square feet of building space  
for a 100 person staff @ 300 square feet per person

**A staff of 100 people, with a 1 % productivity increase,  
would save \$28,000 in salary cost per year.**

TOTAL energy costs for 30,000 square feet of building space  
\$33,000 per year @ \$1.10 per square foot

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## What HVAC Technology can improve IEQ?

### HVAC technology and IEQ

- Temperature
- Humidity
- Fresh Air Ventilation
- Airflow Movement
- Odors
- Contaminants and Pollutants

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE





## HVAC Satisfies This ...



August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## ... some Satisfy This ...



August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



...not Satisfied ...



www.thelindners.com/..Jian\_at\_SLAC.jpg

August 8-11, 2004

www.energy2004.ee.doe.gov

Michael K. West, PhD, PE



...satisfy everyone?



August 8-11, 2004

www.energy2004.ee.doe.gov

Michael K. West, PhD, PE



## HVAC and IEQ

- Complex systems and competing pressures may cause one factor to be overlooked in order to meet another.
  - Relationship between air distribution, thermal comfort, acoustics, energy use, and air quality
- Recent case law holds that the acceptable standard of care now extends beyond the building code.
  - *Standard of Care* is ASHRAE Handbook, which is more rigorous and detailed than most codes
  - The “Good Practice” test

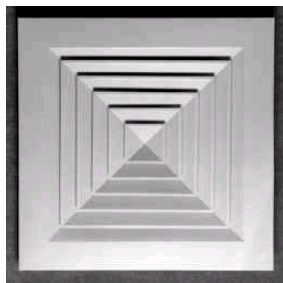
August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## Air Distribution is Critical



- Size - Selection - Noise
- Distance between and to walls
- Adjustment

August 8-11, 2004

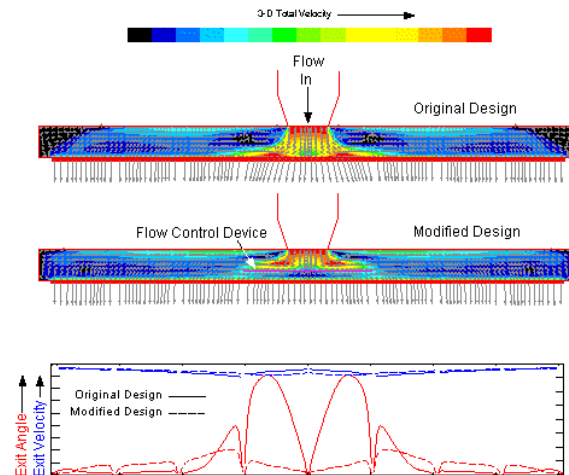
[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE





## Air Distribution is Critical



August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## ❖ Meet or Exceed the requirements of ASHRAE Standard 62

- *Ventilation effectiveness*, design & location of diffusers
- Increase the rate of *pre-conditioned outdoor airflow*
- *Demand-controlled ventilation* on  $\text{CO}_2$  and  $\text{VOC}_{\text{total}}$
- *Monitor indoor and outdoor air quality* with BAS
- Integrate contaminant / odor control systems
  - *Local exhaust at point-sources*
  - High efficiency air filters – rated ASHRAE *MERV-11 or higher*
- Implement rigorous *HVAC Maintenance*
- Thorough *housekeeping regimen*

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



## ❖ Meet or Exceed the requirements of ASHRAE Standard 55

- Provide finer local space temperature control
  - more zones
  - narrow dead-band, high accuracy
  - personal / workstation controls (versus locked thermostat)
- Provide positive control of humidity
  - humidity sensors with BAS, or humidistats
  - install dedicated dehumidification and humidification
  - regular calibration

## ❖ Address CBR Resistance

- *Beyond the scope of this presentation*

August 8-11, 2004

[www.energy2004.ee.doe.gov](http://www.energy2004.ee.doe.gov)

Michael K. West, PhD, PE



The Solutions Network

Rochester, New York

# Thank You !

## Cool, Comfortable, and Productive

Michael West, PhD, PE  
Building Systems Scientist  
Advantek Consulting, Inc.  
[www.advantekinc.com](http://www.advantekinc.com)

**AdvanTek**